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An Empirical Investigation into the Causal Relationship Between Money and Prices in the Post World War II United States

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$$(2) \quad [\ln X(t) - 1.5 \ln X(t-1) + .5625 \ln X(t-2)]$$

which is a second-order filter of the general form:

$$(1 - kL)^2$$

Where: k is set equal to .75,
and L is the lag operator.

His choice of k = .75 in the general form was based on the observation that this filter "approximately flattens the spectral density function of most economic time series, and the hope was tha regression residuals would be very nearly white noise with the prefiltering."[1/]

In assessing the effectiveness of the prefilter, Sims warns that one should not rely on the Durbin-Watson statistic. He notes that the Durbin-Watson statistic fails to adequately test for this due to the fact that autocorrelation remaining after the application of this filter would most likely be of an order greater than one; therefore, the Durbin-Waston statistic is probably inappropriate here. We suggest that an ad hoc method of testing for higher orders of autocorrelation in the error structure is accomplished by performing a general fourth-order autoregression on the residuals. Finding statistically significant coefficients leads to the rejection of the null hypothesis of no autocorrelation.

If the prefiltering fails to adequately remove the serial correlation, the estimates of the coefficients will be consistent, but there will be bias present in the estimates of their variances. If this

bias results in the underestimation of the variance (downward bias), the 't' and 'F' statistics, as well as the R^2 reported in these regressions, may be biased upwards. This could lead to the 'identification' of non-existent or spurious causal relationships. Note that if the bias is in the opposite direction, the significance of the relationship will be understimated, resulting in the failure of the test to identify an existing causal relationship which may be viewed as "spurious independence"[2/]. The relevant point here is that the filter must remove as much of the autocorrelation in the regession residuals of the transformed series as possible. Note that the filter does <u>not</u> necessarily have to remove the autocorrelation present in the transformed input series themselves (of the bivariate system under test). This point is made by Pierce and Haugh [1977, p.22-3].

Mehra [1977] suggests that the choice of an ad hoc filter is not necessarily appropriate, nor is the same filter necessarily appropriate when the regessor and regressand are reversed in the estimation procedure. To overcome this problem, he suggests that the following procedure be used to empirically define a filter which removes the autocorrelation from the residuals for the causality tests. This filter is assumed to be of the second-order, and has the same general form as that presented by Sims [46] and described above $[(1 - 2kl + k^2L^2)]$. However, it differs substantively since the value of k is not defined <u>a priori</u> but is chosen empirically to eliminate the presence of serial correlation in the error structure. The procedure to determine the appropriate value of k is defined as follows:

(i) Form an appropriate specification of the 2-sided lag relation under test; include linear trend and seasonal dummies. Use some ad hoc filter (he suggests $k=.75$) to prefilter the variables. One then applies OLS to estimate the lag profile.

(ii) The autoregressive properties of the residuals in (i) are then examined by performing the following autoregression [where e(t) is defined as the residual in period (t):

$$e(t) = B(1)\ e(t-1) + B(2)\ e(t-2) + B(3)\ e(t-3) + B(4)\ e(t-4)$$

(iii) If the preceding autoregression (ii) indicates that the error structure is uncorrelated, <u>then</u> the choice of the ad hoc value of k is appropriate for the specificaton under test. [ie. B(1), B(2), B(3), and B(4) are statistically insignificant.].

(iv) If the autoregression (ii) indicates the presence of some serial correlation, the value of k is changed and the procedure is repeated for steps (i)-(iv). [Mehra 1977, pps. 1230-1]

It should be noted that the preceding test establishes the proper filter for the function of say m = f (GNP), but for the filter that is appropriate for GNP = f' (m), the procedure must be repeated and a new k defined. Also, if autocorrelation of order greater than 2 is present in

the error structure (as evidence by significant coefficients on e(t-3) or e(t-4), one must use a higher order filter such as $(1-kL)^4$. The specification of a filter such as this is discussed below.

The Model

The relationship between money and prices is obviously of great importance, as well as one for which competing theories have proposed different causal orderings. The neoclassical Quantity Theory of Money holds that changes in the exogenous nominal money stock causes changes in the (passive) price level, and/or the level of real income (Q). The breakdown of the influence of a change in the money stock on the price and quantity components of nominal income depends on the level of aggregate economic activity. An opposing view suggests that the quantity of money is for the most part, statistically endogenous, passively adjusting to changes in the level of economic activity.

The causality test utilized in this study is a modification of the test utilized by Mehra [1977].

The model under test is defined as:

$$(1)\quad M(t)^* = \hat{\alpha} + \sum_{s=-i}^{m} \hat{\beta}_s \, CPI(t-s)^* + \sum_{j=1}^{3} \hat{\psi}_j D_j + \hat{\delta}_t LT + \varepsilon$$

where i is equal to 4 (the number of leads) and m is equal to 8 (the number of lags), with M* and CPI* defined below. D is seasonal dummy.

The null hyopothesis of causality from money to prices cannot be rejected if the coefficients of future prices (CPI(t-s) for i < 0) are

statistically different from zero as a group, or are large in absolute magnitude. In other words, if future prices are significant in explaining current money, a causal ordering exists <u>from</u> money <u>to</u> prices. To complete the investigation of the causal ordering between the two series (to identify the relationship as unidirectional or bidirectional) the following is also tested:

$$(2)\quad CPI(t)^* = \hat{\alpha}_1 + \sum_{s=-i}^{\hat{m}} \hat{\beta}_{1_s} M(t-s)^* + \sum_{j=1}^{3} \hat{\psi}_{1_j} D_j + \hat{\delta}_{1_t} LT + \nu$$

With s and m defined as above.

Here, the null hypothesis of causality from prices to money cannot be rejected if b(i)=0 for all i < 0 (ie. the future values of M are significant in explaining current prices, as a group). The results of these tests are presented in Table V.

To perform the test for causality between money (M) and prices (CPI), four regessions are required. To properly interpret the tests, the removal of serial correlation from the error structure is necessary. To accomplish this, the procedure described by Mehra [1977], as well as a subsequent modification necessitated by the existence of autocorrelation greater than the second order, was used.

Once the value of k is empirically defined for the relationship of money on prices, the entire procedure was repeated for prices on money.

When the appropriate filters have been empirically defined, the question of the Granger-causal ordering between money and prices can be

addressed. In order to accomplish this, the four required regressions on the transformed (logarithmic transformation) and prefiltered data series are estimated:

(A) M=f(P, current, 8 past)

(B) M=f'(P,4 future,current,8 past)

(C) P=f''(M,current,8 past)

(D) P=f'''(M,4 future,current,8 past)

From the results of regressions (A) - (D) above, the statistical significance of the coefficients on the future values of the independent variables in (B) and (D) can be examined a a group. This consists of an F-test:

$$F = \frac{[SSE(r) \; - \; SSE(u) \; / \; (q - p)}{[SSE(u) \; / \; (n - q)]}$$

With the terms in the preceding defined as : SSE(r) is the sum of squared residuals in regression (B) [(D)], SSE(u) is the sum of squared residuals in regression (A) [(C)], q is the number of parameters estimated in (A) [(C)], p is the number of parameters estimated in (B) [(D)], and n equals the number of observations.

Under the null hypothesis that the four future coefficients are statistically insignificant as a group in the two F-tests performed above, the computed F is compared with the table F for the appropriate degrees of freedom, at the .05 level of significance. If the null hypothesis is rejected for money on prices, this means that future prices <u>are</u> significant in explaining current money. If this is the case, a Granger-causal ordering is established from money to prices. The test must be repeated for prices on money. The possible causal ordering here are (i) from money to prices, (ii) from prices to money, (iii) bidirectional causality between the two series, or (iv) no causal relaionship exists.

Results

The data for this study were taken, for the most part, from the Naional Bureau of Economic Research data bank and consist of the seasonally adjusted money stock (narrowly defined) and the Consumer Price Index, also seasonally adjusted. The observations on these two series for 1977:1 was taken from the Federal Reserve Bulletin.

The results of a study by Barth and Bennett [1975] are being critically examined and compared with the results of the present study. To facilitate an accurate comparison of two studies, I performed the same testing procedure presented over their sample period. The results obtained by us using their filter are presented in Table II. The results of their study are reproduced in part in Table I. By comparing the results of the F-tests on the four future coefficients, one notes that the results, for both directions of causality, are extremely similar. This implies that only minor differences in the computational algorithm (and perhaps in some revisions of the data) are present. It is important that the two studies under consideration be essentially the same because I wish to assert that their study allowed significant lower-order autocorrelation to remain after filtering which, as discussed above, biases the results of the causality test. The Durbin-Watson statistics were not reported in Barth and Bennett [1975]; however, I have computed these statistics and reported the results of my testing over their sample period in Table III. It is noted that their filter was successful in removing gross autocorrelation in the relationship of prices on money; but when the regressions of money on prices were run, the filter was deficient in the removal of first-order autocorrelation as is evidenced by the examination of the Durbin-Watson statistic. To verify this, as

Table I

F-Tests on Four Future Coefficients

Results from Barth and Bennett [1973]

Causal Pattern	Regression	F(4,64)
M → CPI	M on CPI	5.090*
CPI → M	CPI on M	2.066

*statistically significant at the .01 level

Table II

F-Test on Four Future Coefficients

This Study's Results Using the Barth/Bennett Sample

Causal Pattern	Regression	F(4,64)
M → CPI	M on CPI	4.956*
CPI → M	CPI on M	2.170

*statistically significant on the .01 level

Table III

Results of Regressions Using Barth/Bennett Sample

	Regression	DW	F	R	SEE
A.	CPI=f(M,8 past)	2.18	15.13	.743	.00487
B.	CPI=f(M8,past,4 fut)	2.17	12.88	.774	.00471
C.	M=f(CPI,8 past)	1.26*	30.64	.854	.00479
D.	M=f(CPI,8 past,4fut)	1.43*	30.06	.889	.00432

*null hypothesis of no autocorrelation rejected at the .05 level

Table IV

Autoregression of Residuals in Table III

Regression	e(t-1)		e(t-2)	
	Coef	t-stat	Coef	t-stat
A.	-.102	0.91	.037	0.33
B.	-.102	0.90	.022	0.19
C.	.341	3.05**	.077	0.69
D.	.278	2.48*	.015	0.13

*significant at the .05 level (2-tailed test)

**significant at the 01. level (2-tailed test)

well as to check for second-order autocorrelation, an autoregression was performed on the residuals of the preceding regressions. In the autoregression of the residuals from money on prices, the null hypothesis of significant coefficients on the lagged error terms [specifically on e(t-1)] cannot be rejected. In both cases, where future coefficients of the 'independent' variable were included, as well as excluded, the residuals of the money on price relationship exhibited first-order autocorrelation. The results of the autoregressions are presented in Table IV. The failure to remove the first-order autocorrelation causes the results obtained in that study to be considered suspect due to the bias in the estimation of the computed F used in the F-test on future coefficients.

The main thrust of the present study is to examine the causal relationship between money and the price level in the post World War II United States. To facilitate this, the model described in the preceding section was tested over the larger sample period, 1951:1 to 1976:1.

After applying a second-order filter to the relationship of prices on money, it was found that third as well as fourth order autocorrelation appeared to be present since the coefficients on the third and fourth lagged error term were significant. Consequently, a higher order filter was specified for the price on money relationship.

The constructon of this complex filter is as follows:

(1) Apply a general fourth-order filter $[(1-kL)^4]$ to both series. The value of k is arbitrarily chosen a priori subject to $0 < k < 1$.

(2) Allowing $M(t)^*$ and $CPI(t)^*$ to equal the transformed [from (1) above] money and price series respectively, the following relationship is estimated using OLS (constant term, seasonal dummies, and linear trend term are also included in this and all subsequent regressions):

$$CPI(t)^* = \sum_{s=-i}^{m} M(t-m)^* \qquad (i=4,\ m=8)$$

(3) The coefficients from (2) are then fit to the <u>unfiltered relationship</u>:

$$CPI(t)' = \sum_{s=-i}^{m} M(t-m) \qquad (i=4,\ m=8)$$

where: CPI' is the vector of fitted values.

A vector of residuals [u(t)'s] is then calculated by subtacting the vector of fitted values [CPI'(t)] from the unfiltered price series [CPI(t)]:

$$u(t) = CPI(t) - CPI'(t) \quad \text{for all } t = 1,2,\ldots,T$$

(4) A fourth-order autoregression is then performed on the u(t)'s:

$$u(t) = \rho(1)\,[u(t-1)] + \ldots + \rho(4)\,[u(t-4)]$$

and estimates of the ρ's are obtained.

(5) The estimated ρ's from (4) are then used to filter both transformed series [M(t)* and CPI(t)* described in (2) above] a second time. Allowing M(t)** to equal the money series that has passed through both filters, the second transformation is decribed as:

$$M(t)^{**} = [M(t)^{*} - \rho(1)\ [M(t-1)^{*} - \rho(2)\ [Mt-2)^{*} - \rho(3)\ [M(t-3)^{*} - \rho(4)\ [M(t-4)^{*}]$$

Prices are transformed using the identical filter.

(6) The following relationship is then estimated using OLS:

$$CPI(t)^{**} = \sum_{s=-i}^{m} M^{**}(t-m) \qquad (i=4,\ m=8)$$

(7) The coefficients from (6) are then fit to the relationship:

$$CPI(t)^{*} = \sum_{s=-i}^{m} M^{*}(t-m)$$

both of which have only passed though the first filter described in (1). From this, residuals are calculated

(8) Steps (4) to (7) can then be repeated as necessary to remove the autocorrelation from the error structure. To determine whether or not this autocorrelation has been removed,

a fourth-order autoregression is performed on the residuals from (6). If the coefficients on all lagged residuals are statistically insignificant, the filter is appropriate. If not, steps (4) through (8) are repeated using the residuals from (7) in (4), until this condition is satisfied.

The regression results for the relationships under test are presented in Table V. Results from fourth-order autoregressions on the residuals are presented in Table VI. The results of the F-tests on the four future coefficients of the explanatory variable for both P on M and M on P (the Sims' test) are contained in Table VII. From these results, this study has found that future prices are significant as a group in explaining current money. Therefore, a causal pattern exists between these two variables running from money to prices ($M \rightarrow CPI$). Also, future money is not significant (over the entire sample) in explaining current prices, consequently causality does not flow from prices to money ($CPI \not\rightarrow M$). These results satisfy the criterion for the identification of a pattern of <u>unidirectional</u> <u>causality</u> from money to prices as defined by Sims [1972] and discussed in detail above. Another, and perhaps more interesting argument can be made that the causal pattern has changed over the period under test. For example, the argument is often made that the inflationary experience of the United States in the 1950's and 1960's was essentially demand-pull in nature, while in the 1970's the inflationary pressures are primarily cost-push. I have attempted to address this issue in a rather rudimentary fashion by suggesting that if the cost-push hypothesis is in fact true for the recent past (1970 and later for example), the magnitude of the F-tests on future coefficients will be affected. Specifically, if demand-pull inflation existed in the 1950's

Table V

Results of Regressions Utilized in the Causality Tests

Regression	DW	F	R	SEE
A. CPI=f(M,8 past)*	1.95	1.57	.19	.00431
B. CPI=f(M,8 past,4 fut)*	2.03	1.83	.27	.00419
C. M=F(CPI,8 past)**	1.85	14.06	.66	.00470
D. M=f(CPI,8 past,4 fut)**	1.97	12.87	.71	.0045

note: all regressions contained the current value of the regressor, seasonal dummies, and a linear trend term.

*Prices on Money utilized a complex fourth-order filter

**Money on Prices utilized a second-order filter

Table VI

Coefficients from Fourth-Order Autoegressions of Residuals from the Relationships in Table V

Regression	e(t-1)	e(t-2)	e(t-3)	e(t-4)
A.	.044	.144	.099	.013
	(0.42)	(1.10)	(1.05)	(0.16)
B.	-.018	.095	.123	.012
	(0.17)	(0.92)	(1.27)	(0.14)
C.	.033	-.155	-.048	-.135
	(0.28)	(1.55)	(0.48)	(1.31)
D.	.036	-.107	.016	-.061
	(0.38)	(1.08)	(0.16)	(0.60)

Table VII

F-Tests on Four Future Coefficients

Causal Pattern	Regression	F(4,89)
M → CPI	M on CPI	3.17*
CPI → M	CPI on M	2.30

* statistically significant at the .05 level

and 1960's and is "overwhelming" the effect of cost-push inflation of the 1970's, the test as described will not be able to identify this change. Note in fact that one of the assumptions made in all causality tests is that the direction of causality does not change over the test period. Intuitively, if the hypothesis of cost-push inflation is relevant for the seventies, one would expect the F-statistic of the future money in explaining prices to be <u>greater</u> for the period following 1970, indicating stronger feedbacks from CPI to M over the more recent past as compared to earlier periods in the sample. In other words, the post-1970 experience under this scenario would tend to offset the demand-pull inflation that dominates the remainder of the sample period. Note that we are unable to directly perform the causality test solely on this later period due to an insufficient number of observations, given the number of parameters to be estimated.

To test for stronger feedbacks in the more recent past, additional subsamples were constructed and the significance of future money in explaining curent prices ($P \rightarrow M$) was tested. The subsamples tested were: [1951:I - 1974:I]; [1951:I - 1970:I]; [1951:I - 1968:I]; [1951:I - 1966:I]; and [1951:I - 1963:I]. If feedbacks have become more important in the later years of the sample (the 70's for example), the computed F-statistics on the future coefficients of money would become larger (the explanatory power of future money in explaining current prices increases) in the post-1970 experience. Finding larger, or significant F's on these future coefficients would lend support to the contention that the feedbacks (which must exist if cost-push inflation is being sustained are more important in recent years that in the past. The necessity of this

is seen by viewing cost-push inflations linkages as $W \rightarrow P \rightarrow M$, the last of which is necessary if the inflation is to continue.

For all of the subsamples described above, a complex fourth-order filter was empirically defined using the procedure described above for each period under test. The results of the estimations of these filtered series are presented in Table VIII. By examing the results of the fourth-order autoregressions on the residuals presented in the Table IX, the relationships appear to have been purged of autocorrelation up to the fourth-order. After successfully filtering each subsample, the F-test was performed on the four future coefficients, the results of which are presented in Table X. Note that the computed F for for the subperiod [1951:I - 1974:I] is statistically significant at the .05 level. It also appears that the calculated F's are growing over time. Since the subsamples are of different lengths, it is not appropriate to compare the F's directly to each other. To overcome this problem, a ratio of the computed F to the .05 critical value of F at the appropriate degrees of freedom has been presented. The examination of these values suggests that the F's are increasing over time, indicative of stronger 'reverse' causation or feedbacks from prices to money in the recent past.

This result lends some support to the cost-push hypothesis outlined above, at least to the extent that the feedbacks appear to be getting stronger, implying that the underlying structure causing inflation is becoming more complex than can be explained by either a simple demand-pull or cost-push model.

Summarizing, this study has found that a pattern of unidirectional causality from money to prices exists in the United States for the period 1951:I - 1976:I. This result lends support to the view that inflation is

Table VIII

Regression Results: CPI on M (all subsamples)

Sample/Regression	DW	F	R^2	SEE	DF
1951:I - 1976:I					
A. CPI=f(M,8 past)	1.95	1.57	.19	.00431	87
B. CPI=f(M, 8 past, 4 fut)	2.03	1.89	.27	.00419	83
1951:I - 1974:I					
C. CPI=f(M,8 past)	2.01	1.89	.24	.00429	79
D. CPI=f(M,8 past), 4 fut)	2.02	2.17	.33	.00413	75
1951:I - 1972:I					
E. CPI-F(m,8 past)	2.04	1.23	.18	.00433	71
F. CPI=f(M,8 past, 4 fut)	2.01	1.49	.27	.00420	67
1951:I - 1970:I					
G. CPI=f(M,8 past)	2.05	10.43	.68	.00433	63
H. CPI=f(M,8 past, 4 fut)	1.96	9.14	.72	.00416	59
1951:I - 1966:I					
I. CPI=f(M,8 past)	2.10	1.45	.26	.00462	55
J. CPI-f(M 8 past, 4 fut)	2.06	1.75	.37	.00442	51
1951:I - 1966:I					
K. CPI=f(M,8 past)	1.97	6.30	.64	.00456	47
L. CPI=f(M,8 past, 4 fut)	1.94	5.48	.68	.00443	43
1951:I - 1964:I					
M. CPI=f(M,8 past)	2.09	0.84	.22	.00516	39
N. CPI=f(M,8 past, 4 fut)	2.08	1.06	.34	.00501	35

Table IX

Results of General Fourth-order Autoregressions on Residuals from All Samples in Table VIII (Coefficient (Std. Error)*

Regression Eqn.	e(t-1)	e(t-1)	e(t-3)	e(t-4)
A	.044 (.106)	.114 (.104)	.099 (.094)	.013 .081)
B	-018 (.105)	.097 (.103)	.123 (.097)	.012 (.084)
C	.012 (.108)	.091 (.106)	.041 (.098)	.014 (.085)
D	-.046 (.108)	.103 (.105)	.102 (.101)	.045 (.806)
E	.-037 (.114)	.075 (.112)	.021 (.104)	.038 (.087)
F	.-065 (.114)	.085 (.112)	.088 (.106)	.004 (.088)
G	.-073 (.121)	.099 (.119)	.094 (.144)	-.028 (.092)
H	-.037 (.121)	.121 (.118)	.129 (.113)	.043 (.093)
I	-.112 (.126)	.011 (.125)	-.022 (.118)	.090 (.095)
J	-.104 (.129)	.015 (.131)	.007 (.127)	-.043 (.100)
K	-.032 (.139)	.030 (.140)	.020 (.133)	-.207 (.106)
L	-.018 (.137)	.066 (.141)	.018 (.135)	.021 (.110)
M	-.121 (.147)	-.065 (.144)	-.139 (.133)	.079 (.107)
N	-.123 (.147)	-.025 (.147)	-.036 (.141)	-.089 (.117)

*standard error in parentheses

TABLE X

F-Tests on Four Future Coefficients

(Consumer Price Index on Money)

Sample	F	(F/.05 Crit. Value)	DF (n1, n2)
1951:I - 1976:I	2.30	.927	(4,83)
1951:I - 1974:I	2.58**	1.036	(4,75)
1951:i - 1972:I	2.10	.838	(4,67)
1951:I - 1970:I	2.25	.893	(4,59)
1951:I - 1968:I	2.27	.887	(4,51)
1951:I - 1966:I	1.66	.642	(4,43)
1951:I - 1964:I	1.58	.598	(4,35)

*equal to the ratio of the computed F to the .05 critical value for the appropriate degrees of freedom

**significant at the .05 level

caused by increases in the money supply, and therefore is essentially a monetary phenomenon. From this, the Monetarist claim that we have been experiencing demand-pull inflation in the United States tends to be supported by this study. This result stands in opposition to the view that the primary cause of inflation lies in the real sector. Under this theory, increasing wages (or other factors that affect production costs) exert upward pressure on the price level. The monetary authorities may then allow the money stock to increase, thus 'accommodating' the increased price level. It may also be argued that the money stock is statistically endogenous, in which case the money stock would increase with nominal income (here we are assuming real output doesn't change; ie. only the price component is affected). In either case, the linkages are assumed to be: $W \rightarrow P \rightarrow M$. In other words, an increase in wages results in higher prices over-all, which are 'passed along' to cover the higher costs of production. The monetary authority may then allow the money stock to increase; either by not taking action to offset this, or by increasing total reserves that exist in the banking system, and the inflation has been 'validated'. From this, we should find prices causing money as a necessary (but not sufficient) condition for empirical substantiation of this claim. The results presented in this study do not lend strong support this line of reasoning in the context of the entire period under test.

It is noted that the results of this paper, particularly with respect to weak feedbacks between prices and money conflict with most studies.[3/] I feel that the reason for this difference lies in the ability of the complex filter developed in this study to remove the higher-orders of autocorrelation that exist in the error structure. The

linear filters employed in this paper are causality preserving, and in all cases appear to have removed gross autocorrelation up to and including the fourth-order. The need to remove autocorrelation of orders as high as the fourth has been documented[4/] and can arise from the seasonal adjustment techniques performed on the quarterly data or from seasonality present in the raw data. When these higher orders of autocorrelation are ignored (when important), the significance of the F-statistic on future regressors can be biased downward, implying that the variances of the 'independent' variables are being overestimated, underestimating the explanatory power of these variables.

After a careful examination of the relevant literature, the results obtained in this study, specifically the identificaion of a shift in the underlying structure of inflation in the post-1970 United States appears to be unique. It can be argued that the application of test such as those used in this study which include seasonal dummies as well as linear trend terms, would not capture many of the 'short-run' fluctuations present in the data. If this is so, tests such as these are more relevant for the 'long-run'. Future explorations into this area might therefore prove to be more fruitful (if not more controversial) if one were to examine the 'short-run'.

The groundwork for examining causality in different analytical time frames is presented in Granger and Hatanaka [1964] in which the strength of the causal relationship can be interpreted as a function of frequency. The importance of this is seen when one defines the long-run identically equal to the low frequency components and the short-run to the high frequencies, and perhaps the middle run to the remaining frequencies. The choice of the "cut-off frequencies" for the definition

of the preceding analytical time frames is somewhat arbitrary, but in general, the determination between the long and short-run is more easily distinguished. The authors offer what they refer to as a "simple (and highly unreal) example" to clarify this point:

> "Consider two stock exchanges in some country, one major importance (A) and the other of lesser importance (B). Clearly B will be likely to follow all the fluctuations, both long and short-run of A so we have $A \rightarrow B$. However A will be unlikely to be affected by short-run fluctuations of B, but may be concerned by the long-run fluctuations. Letting a subscript l denote the low frequency component and a subscript h the high frequency component, we may have:
>
> $$B(l) \rightarrow A(l)$$
> $$B(h) \not\rightarrow A(h)$$
>
> Thus, in this example, feedback will inly occur in the low frequency range."[1964, p 123]

To observe this type of phenomenon would require the use of spectral analysis since we are discussing the frequency rather than the time domain. Intuitively, the time series under test are decomposed into their various frequency components. Then, by examination of the phase[6/] of the low frequency components (interpreted as the long-run), the leading series can be identified at that frequency. This can then be

repeated for the high frequency components (short-run). Admittedly, the strict economic interpretation of such a test is weakened since we must necessarily define the short and long-runs in an historical rather than analytical context. It should be noted however, that if undirectional causality is discovered at all observed frequencies, then the strong argument that the relationship holds in both the long and shor runs could be made. This would be of great importance with respect to the money-price relationship since the primary area of controversy centers on the short-run relationship. Consequently the test remains intuitively appealing and serves as a fertile area for future research.

Endnotes

1/ Mehra [1977] discussed below, disputes this stating that the filter that flattens the spectral density function of the residuals resulting from the estimation of M=f(P) will not necessarily do so for P=f(M).

2/ This phrase is defined in Pierce [1975, p.29] as "...two variables appear independent only because of a common but opposite association with a third variable--this is really a case of spurious correlation, only the correlation is spuriously low rather than spuriously high."

3/ An exception to this offered in Mehra [1978a]. in which a weak feedback system from the GNP deflator to the monetary base in identified over his entire sample period.

4/ See Wallis, K.F. "Testing for Fourth Order Autocorrelation in Quarterly Regression Models" Econometrica Vol. 40 No 4, (July 1972)

5/ Phase is defined as the angular measure of the shift on the time axis of one series relative to another series which maximized coherence (the linear association between two series at the same frequency component) at that frequency.

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